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CALIBRATION OF THE STRUCTURAL ACOUSTICS LOADS AND TRANSMISSION FACILITY AT NASA LANGLEY RESEARCH CENTER

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INTRODUCTION

The Structural Acoustic Loads and Transmission (SALT) facility at NASA Langley Research Center consists of an anechoic chamber, a reverberation chamber and a transmission loss (TL) window. The anechoic chamber and the TL window were added to the existing reverberation chamber in 1998 to enhance the testing capabilities of the facility. The TL window was covered with a heavy fiberboard insert to isolate the anechoic and reverberation chambers for the calibration of each of the rooms. A movable partition with foam wedges was placed in front of the TL window in the anechoic chamber to facilitate acoustic free-field measurements. A hemi-anechoic environment was created by removing the wedges from the floor. The anechoic chamber, the hemi-anechoic chamber, the reverberation chamber and the transmission loss suite were calibrated to have the capability for sound radiation, sound propagation, and sound transmission loss measurements. The frequency range of interest included the 80 Hz to 12,500 Hz one-third octave bands.

DESCRIPTION OF THE FACILITY

The arrangement of the new anechoic chamber, the new TL window and the existing reverberation chamber of the SALT facility at NASA Langley Research Center is depicted in Figure 1. The recently built anechoic chamber is 4.57-m high, 7.65-m wide and 9.63-m long, measured from wedge tip to wedge tip for a volume of 337 m^3. The double walls of the chamber (concrete and sheet rock) were designed to provide 54 dB of sound attenuation at 125 Hz. Two 0.21-m thick, 1.65-m wide and 3.13-m high swinging door assemblies, with reinforced metal facings and interior absorptive materials, were installed to provide access to the room. A heavy, seven-ply fiberboard with a total thickness of 0.146 m was installed in the TL window frame to isolate the anechoic and reverberation chambers and accommodate calibration measurements in each of the rooms. A cross-sectional view of the anechoic chamber showing the TL window is presented in Figure 2. More than 4850 open-cell, polyurethane acoustic wedges were used to cover the walls, the ceiling and the floor in the anechoic chamber. The 0.914-m tall wedges have a 0.3048-m by 0.3048-m by 0.3048-m base with a 0.610-m long, tapered section for a weight of 1.69 kg per specimen. Absorption coefficients ranged from 1.19 at 100 Hz to 2.80 at 5000 Hz. Although an absorption coefficient of 1.0 constitutes total absorption, higher values were obtained as the used Sabine equation does not provide for the three-dimensionality of the samples but only for their projection onto the mounting surface. The movable partition (Figure 1) in front of the TL window was covered with an arrangement of 90 wedges. An hemi-anechoic environment was obtained by removing the wedges from the floor of the anechoic chamber. Figure 1 also shows part of a (closed) flow duct[1] protruding into the anechoic chamber. A high-pressure air system duct may be assembled, running through the anechoic chamber, the TL window and the reverberation chamber to accommodate future measurements on acoustic radiation of flow-excited structures. The 278 m^3 reverberation chamber is structurally isolated from the rest of the building and measures approximately 4.5 m by 6.5 m by 9.5 m. The chamber walls and ceiling are splayed to diminish the effects of standing waves between opposite surfaces and are separated by a 30-inch air gap from the surrounding 0.46-m thick concrete building walls. The total surface area of the walls, floor and ceiling is approximately 290 m^2. Figure 3 shows the splayed walls and ceiling of the reverberation chamber, the flat floor and the TL window. The TL window accommodates 1.41-m by 1.41-m test structures to allow for sound radiation and sound transmission loss measurements.

CALIBRATION OF THE FACILITY

Anechoic and Hemi-Anechoic Chambers. The purpose of the anechoic and hemi-anechoic chambers is to provide a free-field or a partly free-field environment for sound power, sound pressure level, sound intensity and directivity measurements of acoustic sources. Ambient noise levels in the anechoic and hemi-anechoic chamber configurations were measured and the results are listed in Table 1 as a function of the one-third octave band center (1/3 obc) frequency. The international standard ISO 3745[2] specifies that the background level shall be at least 6 dB, and preferably 12 dB, below the sound pressure level to be measured in each frequency band within the frequency range of interest (80–12,500 Hz). Acoustic free-field conditions exist when the sound pressure along a radial from the sound source in the far field is inversely proportional to the distance from that source. Doubling the distance from that source constitutes an approximate 6 dB reduction in sound pressure level. ISO 3745[2] and the American standard ANSI S1.35-1990[3] specify laboratory methods for determining the sound power radiated by acoustic sources in anechoic and hemi-anechoic rooms and their guidelines for the design of the test rooms were followed. In the anechoic chamber, maximum allowable differences between the inverse-square-law calculations and measured levels are ± 1.0 dB in each of the 800 to 5000 Hz one-third octave bands and ± 1.5 dB in each of the other one-third octave bands. The allowable differences in the hemi-anechoic configuration are ± 2.5 dB below the 630 Hz one-third octave band, ± 3.0 dB above the 6300 Hz one-third octave band and ± 2.0 dB for each of the one-third octave bands in between. Acoustic measurements were conducted for both the anechoic and hemi-anechoic chamber configurations to verify compliance with the standards. A 0.241-m diameter Kevlar® cone loudspeaker was placed in the corner of the anechoic chamber to the right of the movable partition (Figure 1). The loudspeaker was positioned halfway between the floor and the ceiling with horizontal clearances of 1.30 m and 1.75 m to the nearest acoustic foam wedge tips. A four-microphone measurement pole was placed at three different locations on the room diagonal to obtain sound measurements at ten equi-distant locations from the loudspeaker source. The four microphones on the pole were mounted 0.914 m apart (Figure 4). The first microphone on the pole was positioned at a distant of 0.914 m from the loudspeaker. All microphones were calibrated with a 114 dB, 1000 Hz reference sinusoidal signal before and after the tests. An amplified pink noise signal was supplied to the loudspeaker source. Deviations of the measured from the inverse-square-law sound pressure levels were calculated and normalized to the measured signals at the far-field microphone location 2.74 m from the source. The deviations are tabulated in Table 2 and are all within the standards except some lower frequencies at two locations close to the corner opposite the sound source (boxed values). The higher deviations were attributed to sound with a long wavelength being reflected from the corner walls. The wedges were removed from the floor to conduct a similar study for the hemi-anechoic configuration of the room. The four-microphone measurement pole in the hemi-anechoic chamber is depicted in Figure 5. Table 3 shows the deviations from the inverse square law for the ten microphone locations. All deviations were within the range permitted by the international standard except for three corner locations at the 80 Hz one-third octave band and one corner location at the 100 Hz one-third octave band (boxed values). Deviations from inverse square law were also measured and calculated for seven microphone locations along a line perpendicular to the TL window to accommodate the sound radiation, sound propagation and sound transmission loss of a test specimen in the anechoic chamber. The seven-ply fiberboard insert was covered with 0.914-m thick acoustic foam to minimize acoustic reflections from the insert. The loudspeaker was hung in front of the acoustic foam center. Table 4 lists the deviations from the inverse square law. Deviations were within the criteria of the international standard except for a few locations near the fiberboard insert and the opposite chamber wall at the lower frequencies. These higher deviations, indicated by the boxed values in the table, were attributed to reflected sound with a long wavelength interacting with the incident sound. The higher deviations for all tests were measured at locations closer than 1.3 m from any of the room boundaries.

Reverberant Chamber. Acoustic measurements were conducted by microphones mounted on tripods 1.67 m above the floor at four different locations in the reverberation room. The locations coincided with the placement of the microphones in a 1975 study of the characteristics of the reverberation room[4] to allow comparison of the results. The ISO Standard 3741[5] and the ASTM Standard E90[6] were used to evaluate the characteristics of the reverberation chamber. One-third octave band ambient noise levels were measured in the reverberation chamber and are listed in Table 1. More than 16 modes were calculated to occur in the 80 Hz one-third octave band and more than 29 in the 100 Hz band. The normal modes need to be evenly distributed over the frequency band, have sufficient bandwidth and their directions should be as uniform as possible. The minimum frequency for a diffuse sound field in the reverberation room was calculated to be 83.2 Hz yielding the 100 Hz and higher one-third octave bands. Reverberation time measurements, including Early Decay Time (EDT), T(20) and T(30), were conducted for the same four microphone locations as those in the 1975 study. The EDT is the estimated time required for a 60 dB decrease in sound pressure level (SPL) based on the SPL decay between 0 dB and –10 dB. The T(20) and T(30) parameters indicate the estimated time required for a 60 dB SPL decrease based on the SPL decays between –5 dB and –25 dB and –35 dB, respectively. The reverberation times were obtained from a sequence of one-third octave band noise bursts generated by a reverberation processor module and transmitted into the reverberation chamber through an amplified loudspeaker system. The speaker system was located in one of the corners of the room to excite all the room modes in the frequency region of interest (80-12,500 Hz). The averaged reverberation times and related reflection coefficients are compared with those from the 1975 analysis[4] of the reverberant chamber in Table 5. The reverberation times in the present study are shorter due to added absorption by the new TL window and a temporary, lighter plywood panel covering the opening of the flow duct in the opposite wall. The minimum distance from the microphone to the test panel and any of the room boundaries[3] was calculated to be 2.42 m for the 80 Hz one-third octave band and 1.92 m for the 100 Hz one-third octave band. A microphone was mounted on a rotating boom with a radius of 0.97 m to measure the power level of a sound source in the reverberation chamber[5]. The center of the rotating boom was located half the distance between the floor and the ceiling (2.25 m). The plane of the microphone traverse was under a 10-degree angle with the floor and under a greater angle with the skewed surfaces of the ceiling and the walls. The microphone had a 2.06-m clearance with any room surface exceeding half-the-wavelength of the lowest (100 Hz) one-third octave band for which the sound was diffuse. The same configuration was used to conduct sound transmission loss measurements. The measured levels were well above the ambient noise levels so that no corrections for that purpose were necessary. The sound power level produced by the source in each one-third octave band was calculated from the equation given in ISO 3741[5].

Transmission Loss Suite. The TL window frame was installed on four isolators in the wall of the reverberation chamber. The reverberation and anechoic chambers are only connected by a rubber slab to prevent structural vibrations from being transmitted into the anechoic chamber. Concrete supports with steel fairings and multiple layers of lead, similar to the design of the NASA Langley Transmission Loss Apparatus[7], provide high noise attenuation. No flanking paths were found from sound pressure and intensity level measurements around the TL window in the anechoic chamber with the heavy, 101.6 kg/m^2 mass-per-unit-area fiberboard installed. The transmission loss of a partition is defined in ISO Standard 140[8] as ten times the common logarithm of the ratio of the incident sound power relative to the transmitted sound power. The sound power transmitted through 3.175 mm and 6.35 mm thick rubber test panels installed in the TL window was measured and compared with the calculated mass-law transmission loss to calibrate the TL suite. A diffuse sound field was set-up in the reverberation chamber and was measured by a microphone at the end of the 0.97-m rotating boom. Sixty-four seconds of pink noise, generated by a loudspeaker in one of the corners of the reverberation chamber, was processed by a one-third octave band real time analyzer. Two full rotations of the boom were included in the 32-second exponential averaging analysis. The sound pressure level measured by the rotating microphone is the same as the pressure incident on the test panel assuming a diffuse sound field in the reverberation chamber. Guidelines in ISO Standard 140[8] were followed to obtain the sound power transmitted through the two rubber panels into the anechoic chamber. Sound pressure level measurements were conducted at thirteen locations in the anechoic chamber on a plane parallel to the test panel at a distance of 1 m. Four microphones were mounted on a rotatable boom, at distances of 0.425 m and 0.85 m on opposite sides of the center (Figure 6). Twelve distributed microphone measurements were obtained by rotating the boom -60 degrees, 0 degrees and +60 degrees. A single microphone on a separate stand was used to obtain the thirteenth microphone measurement. The microphone measurement plane needs to be infinitely large to capture all the sound radiated from the test panel. However, finite surface areas were assigned to each of the microphones as the sound power contributions were assumed small at greater distances from the test panel. The mean one-third octave sound pressure levels for the thirteen microphone signals, adjusted for their measurement areas, were calculated and their differences with the average sound pressure levels measured in the reverberation chamber are listed in Table 6. The mass law TL of the two limp rubber reference panels were calculated (Table 6). Doubling of the panel thickness doubles the surface mass of the panel and results in an additional transmission loss of up to 6 dB. The measured and calculated SPL differences for the 3.175-mm and 6.35-mm thick panels are listed in Table 6 (Delta meas and Delta calc) and are well within 1 dB of the expected 6 dB value (100–1600 Hz one-third octave bands). The TL correction factors were obtained by subtracting the calculated limp-mass TL of the two rubber reference panels from the measured average SPL difference for each one-third octave band (Table 6). The TL correction factors for the two panels compare very well having a deviation of ± 0.4 dB from a 16 dB average value between 100 Hz and 1600 Hz. The TL correction factors are valid for the current test configuration and for the conditions discussed in this report. Other calibration procedures may be established to include built-up structures and structures of different size and geometry. Alternative measurement procedures, such as intensity methods, and other measurement locations may be preferred to accommodate different test objectives.

CONCLUSIONS

Measurements were conducted and results were analyzed to calibrate different test configurations of the Structural Acoustic Loads and Transmission (SALT) facility at NASA Langley Research Center. Test arrangements included free-field sound pressure level measurements in the anechoic and hemi-anechoic chambers, diffuse field testing in the reverberation chamber, and sound transmission loss (TL) measurements for panels mounted in the window between the two rooms. Sound measurements were conducted as a function of distance along diagonal lines in the anechoic and hemi-anechoic chambers from a pink noise source over a frequency range including the 80 Hz to 12,500 Hz one-third octave bands. Sound propagation was also measured in the anechoic chamber along a line perpendicular to the TL window with a sound source placed in front of the window and separated by 0.914 m of acoustic foam. The deviations from inverse square law were within the criteria set by international standards for all one-third octave bands between 80 Hz and 12,500 Hz at locations at least 1.3 m away from any boundaries. For locations closer than 1.3 m higher deviations were measured in some of the one-third octave bands below 200 Hz, due to the long wavelength of the sound and interaction of the incident and reflected waves. The reverberation chamber was calibrated to produce a diffuse field over a frequency range from 100 Hz to 4000 Hz. Results in the 80 Hz one-third octave band might produce acceptable diffusitivity for certain measurements as only part of this frequency band fell outside the criteria set in the standards. The TL suite was calibrated for measurements on flat homogeneous panels. TL correction factors were obtained for specific microphone locations in the anechoic chamber to correct for the area over which the transmitted sound power was calculated. Consistent TL results were found for two limp, rubber panels (3.175-mm and 6.35-mm thick) that were assumed to behave according to mass law over a frequency range from the 100 Hz to the 1600 Hz one-third octave bands. The current calibration may serve as a reference to evaluate other configurations for which the precise setup and test structure specifications are known. This work was performed under Contract NAS1-96014, Dr. Richard J. Silcox, Technical Monitor, NASA Langley Research Center.

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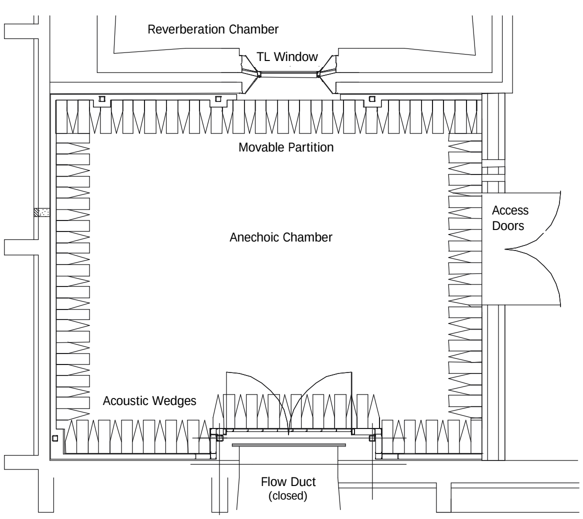

Figure 1. Reverberation chamber, anechoic chamber and the transmission loss window.

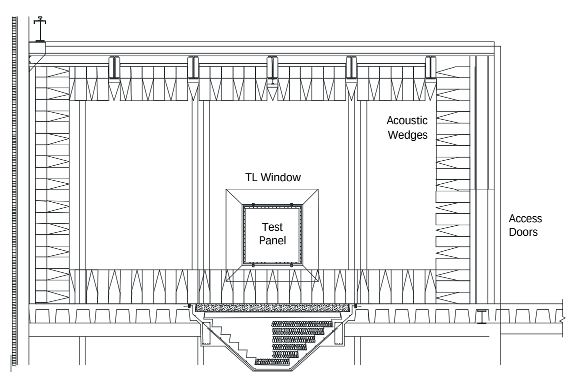

Figure 2. Cross-sectional view of the anechoic chamber showing the transmission loss window. (The stairwell was filled with absorptive materials and covered by a slab of concrete.)

Figure 3. Microphone on rotating boom for diffuse sound field measurements in the reverberant chamber

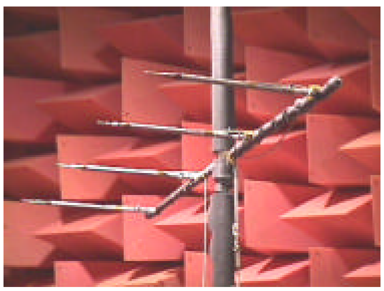

Figure 4. Close-up of the four-microphone measurement pole.

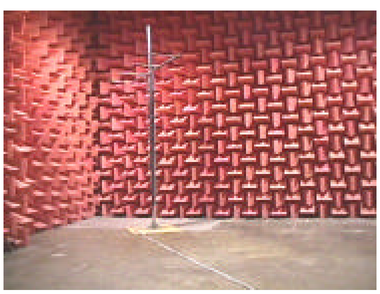

Figure 5. Hemi-anechoic chamber showing the four-microphone measurement pole.

Figure 6. Four microphones on the rotatable boom in horizontal position.

Table 1. Measured ambient noise levels in the test rooms

1/3 obc frequency [Hz]	1/3 obc number [-]	Anechoic Chamber [dB]	Hemi-anechoic Chamber [dB]	Reverberant Chamber [dB]
80	19	32	33	34.4
100	20	28	31	32.1
125	21	28.4	33	43.2
160	22	30.3	30	27.6
200	23	21.3	27	26.9
250	24	19.8	26	28.9
315	25	14.9	24	22.6
400	26	14.2	23	20.7
500	27	9.4	17	12.4
630	28	9.3	19	12.6
800	29	8.1	16.5	12.3
1000	30	6	15.5	10.2
1250	31	6.5	14.5	9.5
1600	32	6.7	12.5	7.6
2000	33	6.5	9.5	7
2500	34	7.8	10	6.3
3150	35	8.3	9.5	6.7
4000	36	9	9	7.6
5000	37	10.2	10	8.3
6300	38	10.8	10.5	8.4
8000	39	11	10.5	8.7
10000	40	11.3	11	7.9
12500	41	11.4	11	7.6

Table 2. Inverse-square-law sound pressure level deviations at ten diagonal microphone locations from a pink noise source in a corner of the anechoic chamber. (Boxed values are outside the range specified by the international standard.)

1/3	Microphone Distance from Pink Noise Source [m]									
obc	0.91	1.83	2.74	3.66	4.57	5.49	6.40	7.32	8.23	9.14
Freq	Sound Pressure Level Deviation in the Anechoic Chamber									
[Hz]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]
80	0.1	0.2	0.0	-1.0	-0.7	-0.7	-0.9	-0.1	-2.4	$\boxed{-6.8}$
100	-1.6	-0.5	0.0	0.8	-0.1	-0.6	0.9	0.4	$\boxed{2.1}$	$\boxed{-3.6}$
125	1.2	0.0	0.0	0.4	1.8	1.8	2.1	2.8	$\boxed{4.0}$	$\boxed{4.0}$
160	0.7	0.5	0.0	-0.3	-0.6	0.7	1.1	2.3	$\boxed{3.0}$	$\boxed{5.5}$
200	0.3	-0.3	0.0	0.2	-0.7	-1.4	-0.8	-0.4	0.5	$\boxed{2.9}$
250	0.6	0.7	0.0	0.2	0.3	0.0	-0.7	-1.0	-1.6	0.4
315	0.3	0.1	0.0	0.4	0.3	0.2	0.6	-0.4	-1.4	-2.3
400	0.2	0.6	0.0	-0.1	-0.1	-0.6	0.0	1.2	0.8	0.3
500	0.9	0.4	0.0	0.0	0.5	0.3	-0.5	-0.3	-0.1	1.3
630	0.1	0.1	0.0	-0.8	-0.1	-0.4	-1.0	0.2	-0.5	-2.2
800	-0.6	-0.8	0.0	-1.1	-1.0	0.0	-1.3	-1.0	0.1	-0.6
1000	-0.7	0.4	0.0	0.9	0.6	0.2	0.5	0.7	0.9	0.0
1250	0.1	0.5	0.0	1.3	0.5	-0.6	1.1	0.7	-0.7	0.9
1600	-0.6	-0.5	0.0	0.5	-0.9	0.1	0.6	-0.5	-0.3	0.7
2000	0.6	1.1	0.0	-0.4	1.0	0.6	0.6	1.2	1.2	1.2
2500	-0.4	-0.6	0.0	-0.6	-0.6	-0.6	-1.5	-0.6	-0.8	-1.2
3150	0.2	0.0	0.0	0.8	-0.4	-0.3	0.2	0.0	-0.6	0.0
4000	0.0	0.2	0.0	-0.3	0.1	-0.3	0.2	0.0	-0.1	0.1
5000	0.4	0.1	0.0	0.0	-0.2	-0.4	-0.5	-0.1	-0.1	-0.3
6300	-0.1	0.3	0.0	0.2	0.0	-0.2	0.1	0.0	-0.3	-0.2
8000	-1.1	0.1	0.0	0.3	-0.2	-0.4	-0.3	-0.1	-0.3	0.0
10000	-0.5	0.4	0.0	0.2	-0.3	0.6	1.1	-0.2	1.7	2.2
12500	-1.7	0.2	0.0	0.4	0.5	0.4	0.6	0.9	1.0	1.3

Table 3. Inverse-square-law sound pressure level deviations at ten diagonal microphone locations from a pink noise source in a corner of the hemi-anechoic chamber. (Boxed values are outside the range specified by the international standard.)

1/3	Microphone Distance from Pink Noise Source [m]									
obc	0.91	1.83	2.74	3.66	4.57	5.49	6.40	7.32	8.23	9.14
Freq	Sound Pressure Level Deviation in Hemi-Anechoic Chamber									
[Hz]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]
80	-1.6	-0.3	0.0	-0.1	-2.8	-1.7	-4.8	-6.4	-7.6	-11.0
100	-1.7	-1.8	0.0	1.1	0.9	1.0	2.5	2.1	1.3	-3.4
125	2.5	1.8	0.0	-0.4	1.5	2.9	3.1	2.1	3.6	3.2
160	-0.7	-1.2	0.0	-1.9	-1.3	-0.3	-0.7	2.1	2.6	2.5
200	0.9	0.6	0.0	1.8	1.2	0.7	-2.5	-2.9	0.7	1.1
250	-0.7	0.0	0.0	0.2	-2.4	-0.3	2.0	1.3	-1.9	-1.6
315	0.5	0.6	0.0	0.8	1.7	1.5	0.3	1.0	2.5	1.8
400	0.2	0.3	0.0	0.1	0.0	0.1	0.9	1.7	1.4	-1.7
500	0.4	0.2	0.0	-0.9	0.2	0.7	0.2	-2.0	1.3	4.6
630	-0.3	-0.1	0.0	-1.4	1.0	0.3	-1.0	1.2	-0.5	-1.5
800	-0.6	-0.9	0.0	-1.2	-1.3	0.5	-0.5	-0.2	1.5	0.1
1000	-0.6	0.1	0.0	0.6	0.7	0.4	1.3	0.7	1.8	1.1
1250	-0.1	0.8	0.0	1.2	0.4	-0.5	2.2	1.2	-0.1	1.4
1600	-0.8	-0.9	0.0	-0.1	-1.3	0.2	0.5	-0.4	0.4	0.9
2000	0.3	0.9	0.0	-1.1	0.9	0.0	0.4	1.6	0.9	1.2
2500	-0.3	-0.4	0.0	0.1	-1.1	-0.8	-1.3	-0.3	-0.8	-1.4
3150	0.3	0.3	0.0	0.6	-1.0	-0.5	0.2	-0.3	-0.6	-0.2
4000	-0.4	0.1	0.0	-0.6	-0.9	-0.6	-0.4	-0.7	-1.0	-0.6
5000	-0.7	-1.0	0.0	-0.3	-1.5	-1.0	-1.2	-1.4	-1.2	-1.8
6300	-1.6	0.2	0.0	0.1	-0.1	-0.9	-0.3	-0.4	-0.4	-0.7
8000	-0.8	-1.3	0.0	0.3	-0.1	-0.5	-0.3	-1.0	-0.2	0.4
10000	0.2	-0.2	0.0	0.4	-1.1	0.6	-0.9	-2.5	0.4	0.9
12500	-0.5	0.0	0.0	0.9	0.6	0.3	0.4	0.4	0.6	0.7

Table 4. Inverse-square-law sound pressure level deviation at seven microphone locations perpendicular from a pink noise source, separated from the heavy partition in the TL window and backed by 0.914 m acoustic foam. (Boxed values are outside the range specified by the international standard.)

1/3	Microphone Distance from Pink Noise Source [m]						
obc	0.91	1.83	2.74	3.66	4.57	5.49	6.40
Freq	Sound Pressure Level Deviation in Anechoic Chamber						
[Hz]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]
80	2.4	0.0	-0.9	-1.9	-2.5	-2.1	-2.2
100	1.5	0.0	-0.6	-2.1	-2.4	-4.4	-3.1
125	1.7	0.0	-1.1	-1.1	-2.0	-2.9	-4.2
160	-0.4	0.0	-0.3	-1.3	-1.7	-2.3	-3.0
200	0.0	0.0	0.5	0.4	0.0	-0.8	-1.6
250	0.4	0.0	0.6	0.8	0.6	0.4	0.0
315	0.5	0.0	0.0	0.3	0.6	-0.2	0.1
400	0.4	0.0	0.5	1.0	1.7	1.5	1.5
500	0.8	0.0	-0.3	-0.5	0.3	0.4	1.1
630	0.5	0.0	0.0	-0.9	-0.9	-0.5	0.5
800	0.4	0.0	-0.3	-0.5	-1.3	-1.0	-1.5
1000	0.2	0.0	-0.7	-0.9	-0.2	-0.5	-1.6
1250	0.1	0.0	-0.2	-1.2	-0.8	-0.3	-1.8
1600	0.2	0.0	-0.4	-0.8	-0.9	0.5	0.3
2000	0.2	0.0	-0.2	-0.9	-0.5	-0.5	0.2
2500	-0.2	0.0	-0.3	-0.7	-0.8	-0.4	-0.5
3150	0.0	0.0	0.0	-0.2	-0.3	-0.6	-1.4
4000	-0.4	0.0	0.1	0.1	0.2	-0.9	-1.1
5000	-0.3	0.0	0.3	0.6	0.6	0.3	-0.4
6300	0.1	0.0	-0.2	0.5	0.7	0.3	0.1
8000	0.6	0.0	0.0	-0.1	0.1	-0.1	-0.6
10000	1.3	0.0	0.3	-0.3	0.2	0.1	0.3
12500	-2.0	0.0	-0.8	-1.6	-1.1	-2.0	-1.7

Table 5. Comparison of averaged time parameters for a 60 dB band noise decay and the room reflection coefficients for the original and modified reverberation rooms.

1/3	Reference 5 (1975)		Reverberation Time			(T20)
obc	Average	Reflection	Average	Average	Average	Reflection
Freq	T60	Coefficient	EDT	T20	T30	Coefficient
[Hz]	[s]	[-]	[s]	[s]	[s]	[-]
80	41.9	99.62	20.43	23.28		99.33
100	26.5	99.4	13.45	15.01	13.40	98.96
125	15.6	99.98	12.28	13.52		98.84
160	17.4	99.08	13.32	14.16	14.60	98.90
200	21.6	99.26	14.31	15.78	16.10	99.01
250	19	99.16	14.42	15.31	15.45	98.98
315	18.1	99.12	14.93	14.85	14.66	98.95
400	17.3	99.08	13.31	13.74	13.88	98.86
500	16.4	99.02	11.98	12.42	12.46	98.74
630	13.7	98.8	10.57	10.75	10.77	98.55
800	11.9	98.7	9.24	9.43	9.46	98.34
1000	11.4	98.6	8.50	8.41	8.38	98.14
1250	9.9	98.4	7.17	6.97	7.00	97.76
1600	8	98	5.74	5.75	5.70	97.28
2000	6.8	97.7	5.00	5.13	5.10	96.95
2500	6.7	97.6	4.30	4.33	4.38	96.39
3150	5.8	97.2	3.48	3.54	3.60	95.59
4000	4.6	96.5	2.53	2.60	2.64	93.98
5000	3.7	95.7	1.89	1.95	1.96	91.97
6300	2.6	93.9	1.46	1.48	1.47	89.42
8000	2.3	93	1.04	1.07	1.05	85.40

Table 6. Measured uncorrected transmission loss, calculated transmission loss and the resulting TL correction factors.

	Measured SPL difference		Calculated TL		Delta meas	Delta calc	TL factor	TL factor	TL factor
1/3 obc Freq	3.175 mm thick	6.35 mm thick	3.175 mm thick	6.35 mm thick			3.175 mm thick	6.35 mm thick	average
[Hz]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]
80	15.59	20.00	5.8	10.4	4.41	4.6	9.79	9.60	9.70
100	22.54	28.05	7.1	12	5.51	4.9	15.44	16.05	15.75
125	24.10	29.89	8.6	13.8	5.79	5.2	15.50	16.09	15.80
160	25.85	31.66	10.4	15.8	5.81	5.4	15.45	15.86	15.66
200	27.91	33.83	12	17.6	5.92	5.6	15.91	16.23	16.07
250	29.98	35.55	13.8	19.5	5.57	5.7	16.18	16.05	16.12
315	31.94	37.82	15.7	21.5	5.88	5.8	16.24	16.32	16.28
400	33.75	39.69	17.6	23.6	5.94	6	16.15	16.09	16.12
500	35.75	41.81	19.5	25.5	6.06	6	16.25	16.31	16.28
630	37.43	43.76	21.5	27.5	6.33	6	15.93	16.26	16.10
800	39.59	46.35	23.6	29.5	6.76	5.9	15.99	16.85	16.42
1000	40.77	47.59	25.5	31.5	6.82	6	15.27	16.09	15.68
1250	43.33	49.78	27.4	33.4	6.45	6	15.93	16.38	16.16
1600	45.29	51.62	29.5	35.6	6.33	6.1	15.79	16.02	15.91